Actinic light source based on LPP for HVM mask inspection applications

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ISTEQ: Overview

Spinoff from EUVLabs / RnD-ISAN:

- EUVLabs/Rnd-ISAN is a well-known research company (located in Moscow), which focuses on EUV light research activities
- Employees of ISTEQ/EUVLabs/Rnd-ISAN are co-authors of 60+ EUV patents

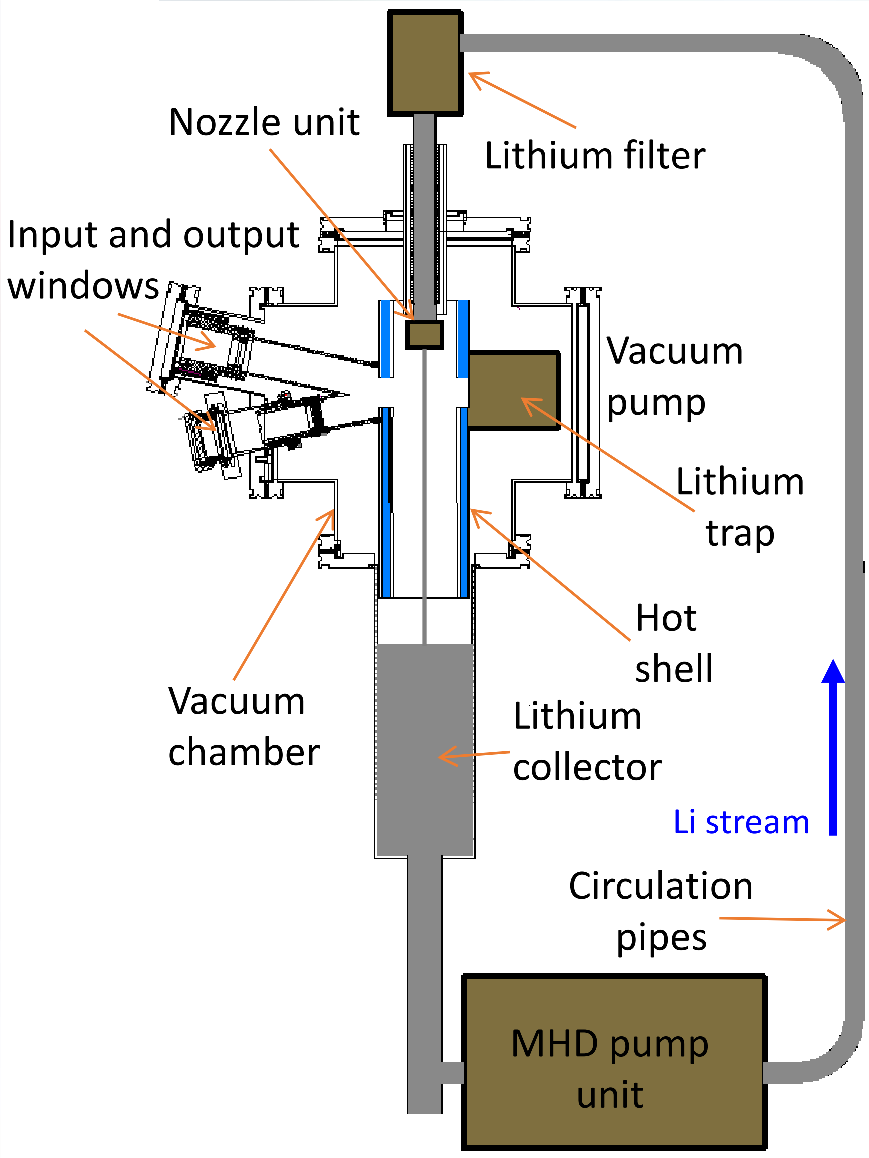
Our main expertise: extremely high level of experience and dedicated team of engineers and scientists

- Plasma light source products and development for various applications
- EUV LPP/DPP light sources for semiconductor applications and metrology
- Metrology equipment for UV, EUV and X-ray
- Modelling and simulations of fundamental physical processes

Company group ISTEQ/EUVLabs/RnD-ISAN includes 50+ R&D specialists

ISTEQ B.V. is located in the High Tech Campus, Eindhoven, The Netherlands

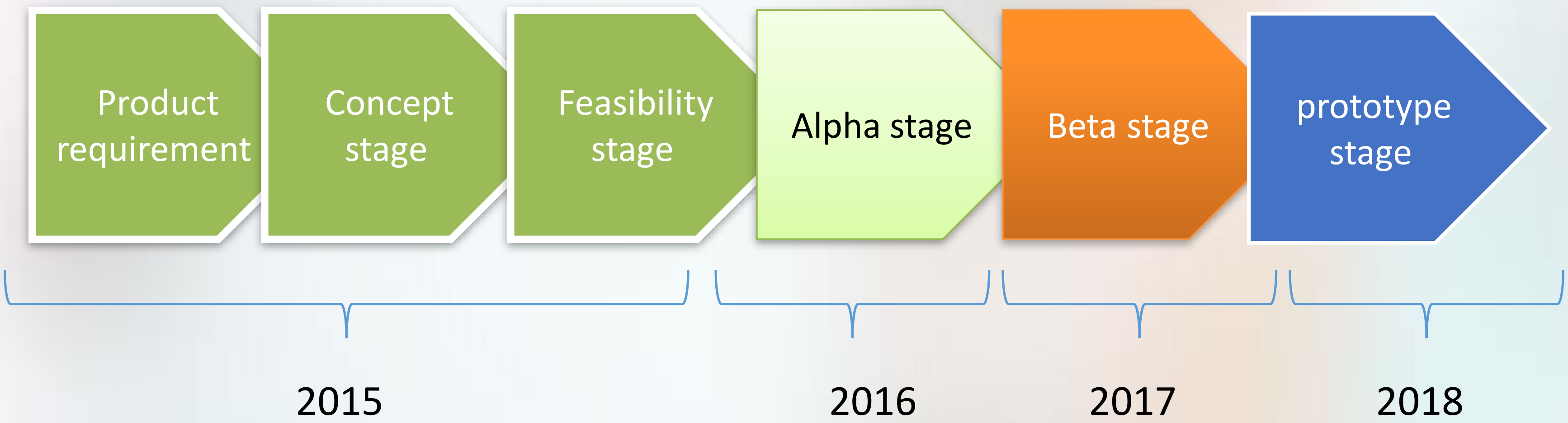
Li source system layout



Key technologies of the source:

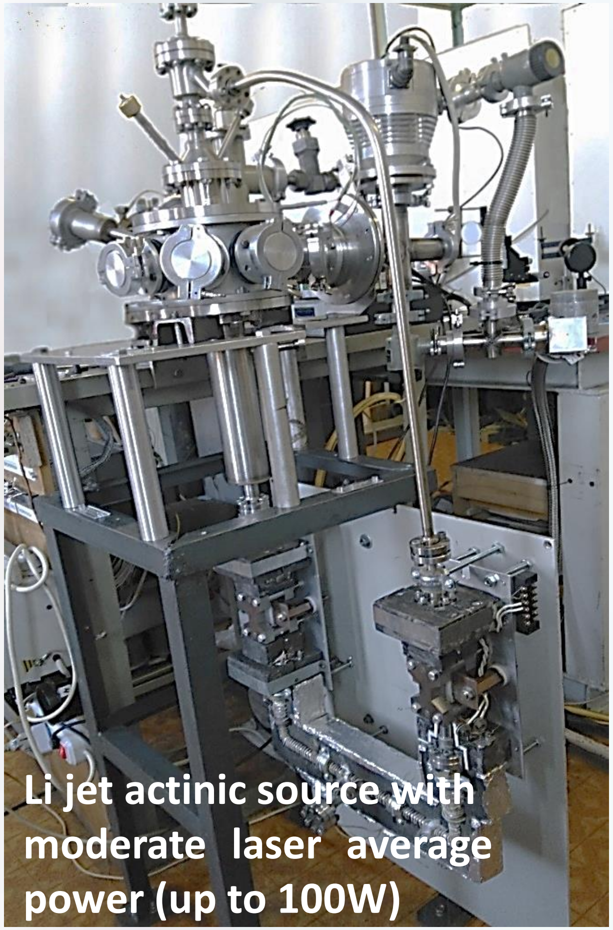
- Li jet - target
- Circulation system of liquid lithium fuel based on MHD pump system
- Self-cleaning input laser windows
- Self-cleaning output EUV windows

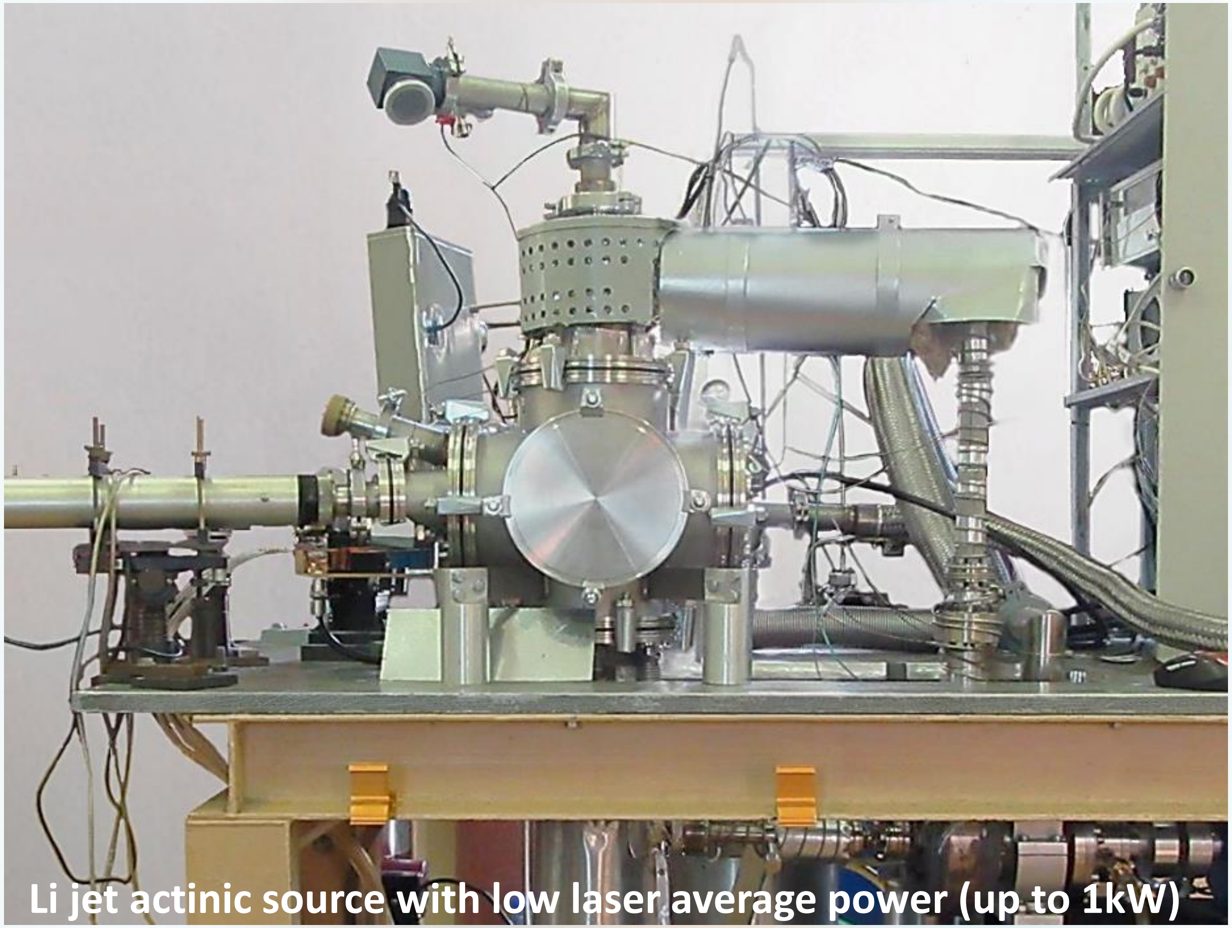
Li source product development status



- Prototype development and characterization
  - Power, brightness, stability, debris quantification and debris mitigation
  - Components lifetime, reliability robustness, service and maintenance
- Customer demonstration to validate the results achieved

Li jet-beta sources


Li jet actinic source with moderate laser average power (up to 100W)

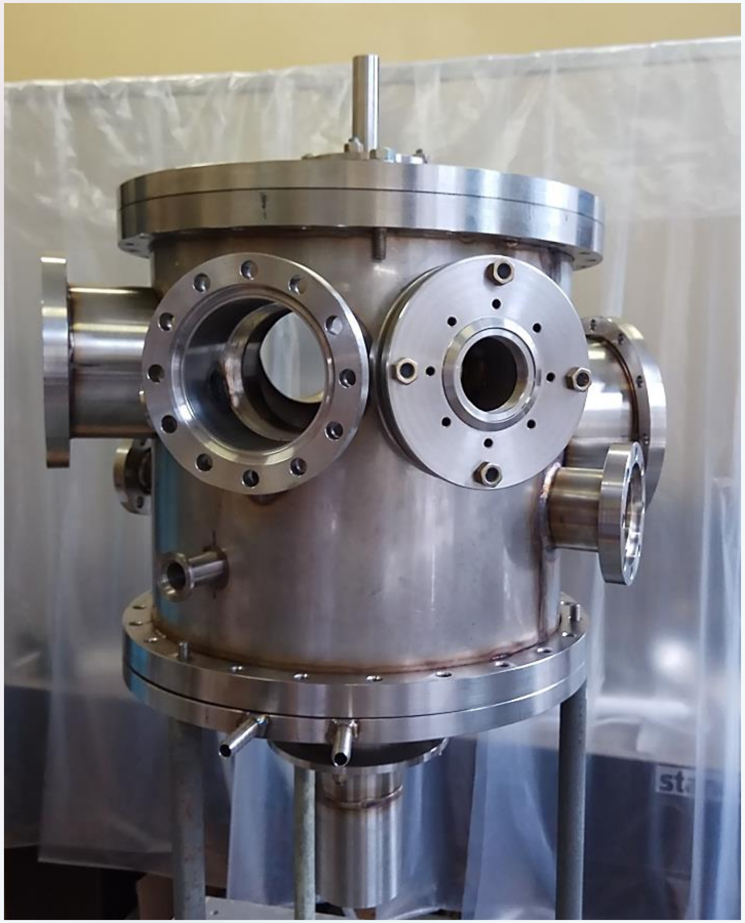

Li jet actinic source with low laser average power (up to 1kW)

Main source components:

- Vacuum chamber
- TM pumps
- Self-cleaning systems
- Input/output optical windows
- Lithium closed loop with a MHD pump system and lithium cleaning system

Source dimensions: H x W x D=1500mm x 1000mm x 1000mm, weight: 150 kg.

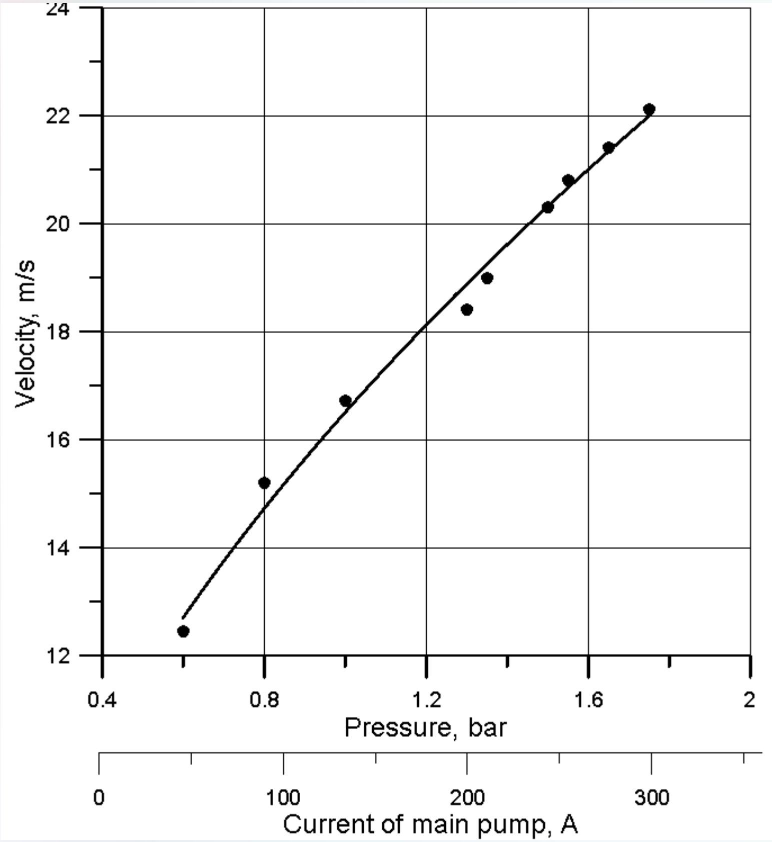
Li jet-prototype source to be assembled Q2. 2018



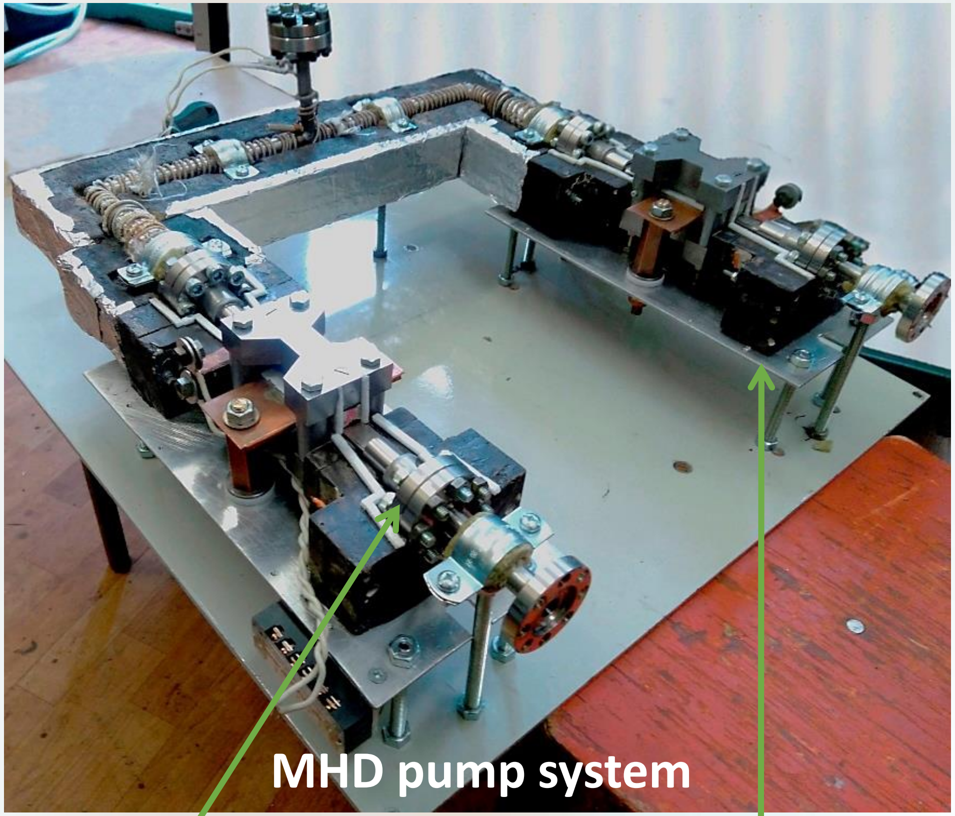
- System designed as per customer requirements
- Li jet target
- Drive laser 1kW+
- Full recycling Li system with filtering
- To run 24/7
- Minimum downtime
- Debris free
- Brightness – up to 1000+ W/(mm^2·sr·nm) at the plasma

Target management: Li recycling system

Li liquid jet target circulated in a closed loop via MHD pumps



Li jet velocity vs pressure an current of main MHD pump



Main MHD pump

Auxiliary MHD pump

Self-cleaning input/output windows

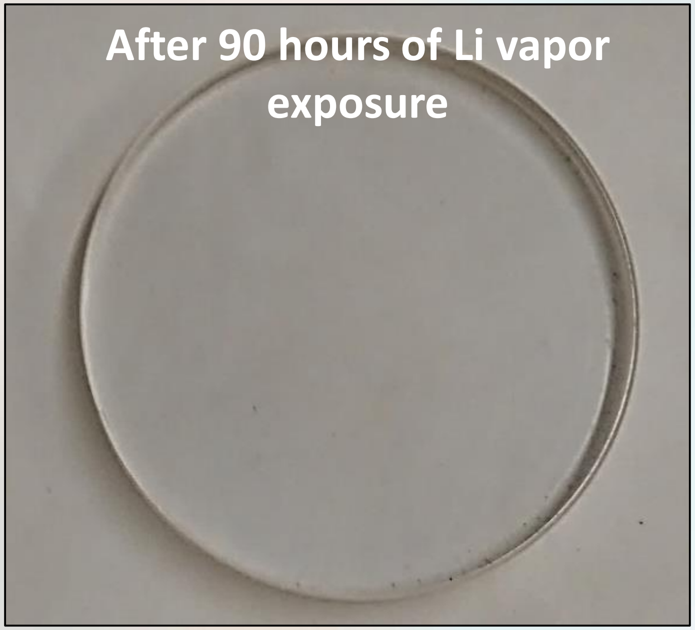
Self-cleaning input/output window for small-scale debris and Li vapor

- The laser input window's materials transmit the laser beam and has the ability to be heated to a high temperature
- Output window is based on the use of a composite filter with high transmittance in band 13.5 nm and high rate of lithium evaporation from the surface of the filter. This provides complete protection of the collector mirror from debris.

Input/output window unit with self-cleaning system

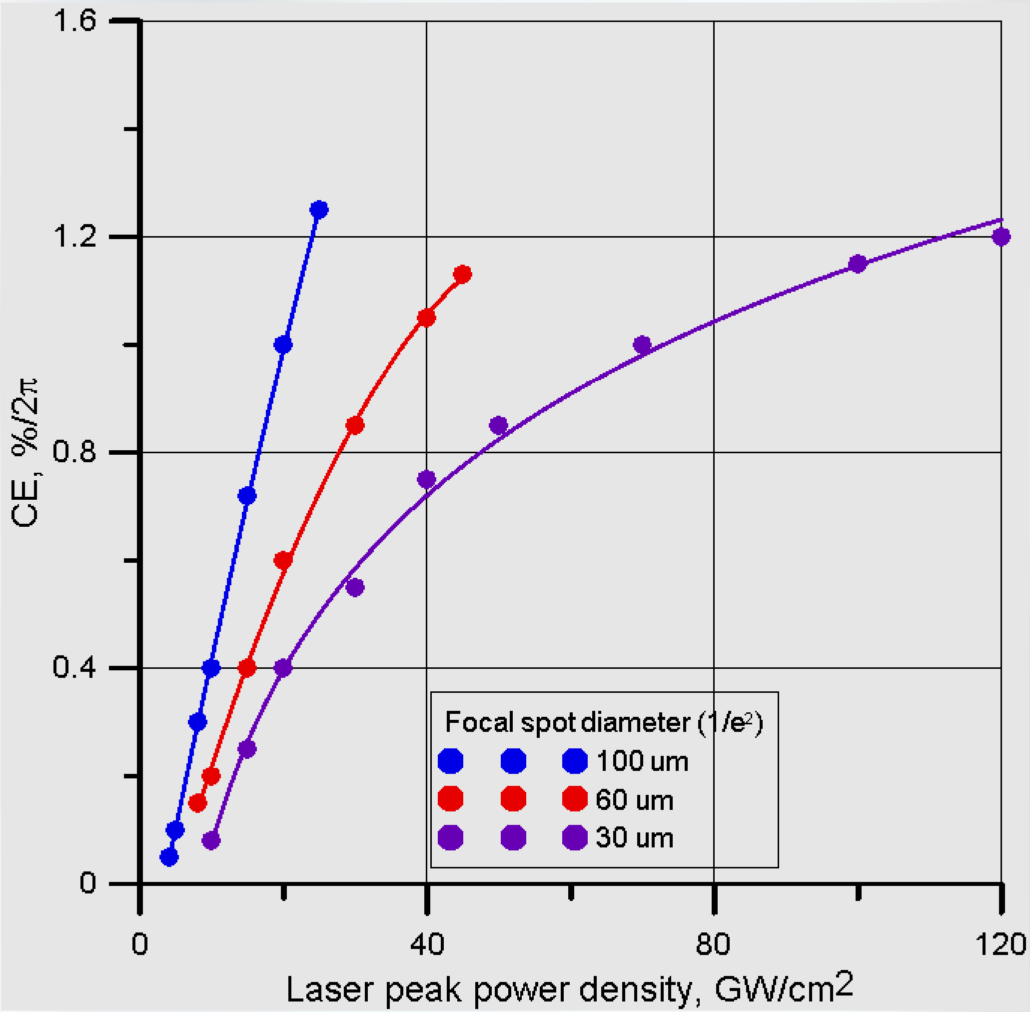
Self-cleaning input laser window

The self-cleaning technology of the input window for small-scale debris and Li vapor flying towards the laser beam direction is based on specially treated sapphire and high rate of lithium evaporation from the surface of the window.



No noticeable changes in transparency for laser radiation have been measured. The self-cleaning system ensures rapid cleaning of lithium debris during source operation.

CE vs laser power density



Drive laser: Nd-YAG laser,

Pulse energy range: 0.6-20mJ

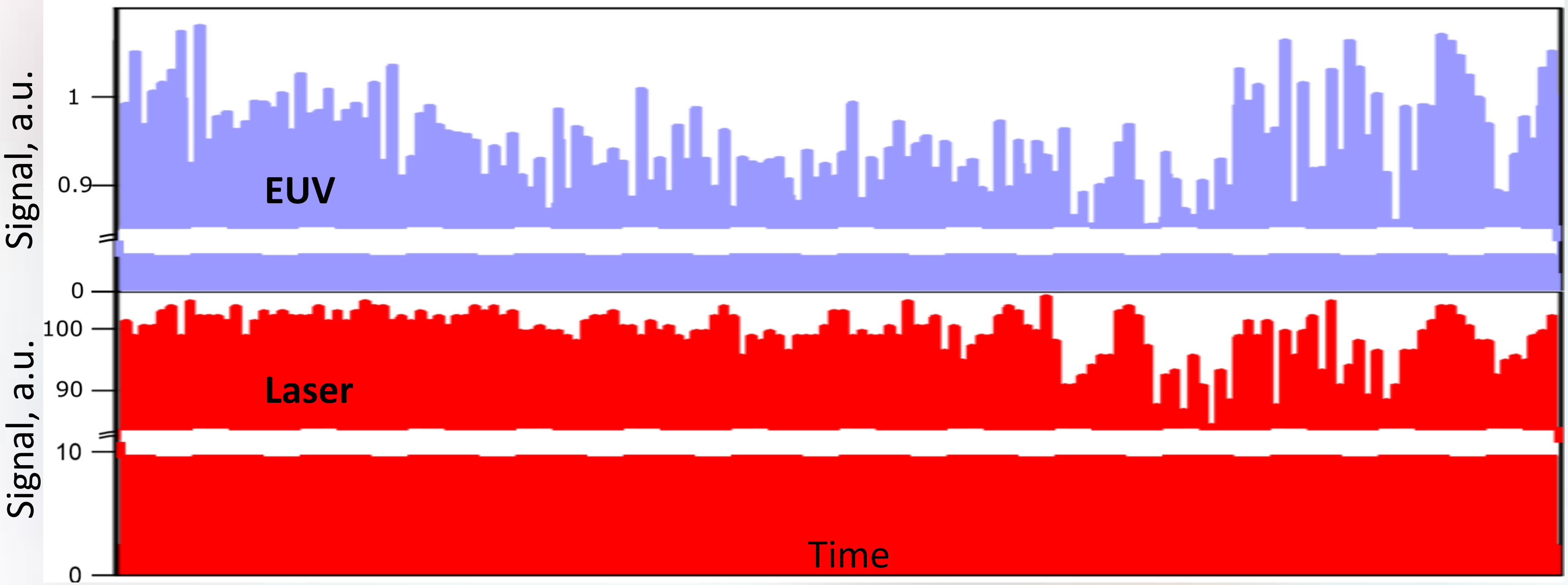
Pulse duration: 15 ns

Changing various laser parameters to achieve the best CE along with customer requirements

Long term source operation

Life time was checked by Nd-YAG laser with PRR of 2 kHz, power density $0.9 \cdot 10^{10}$ W/cm^2 and pulse duration of 50 ns at operation near the threshold of EUV generation

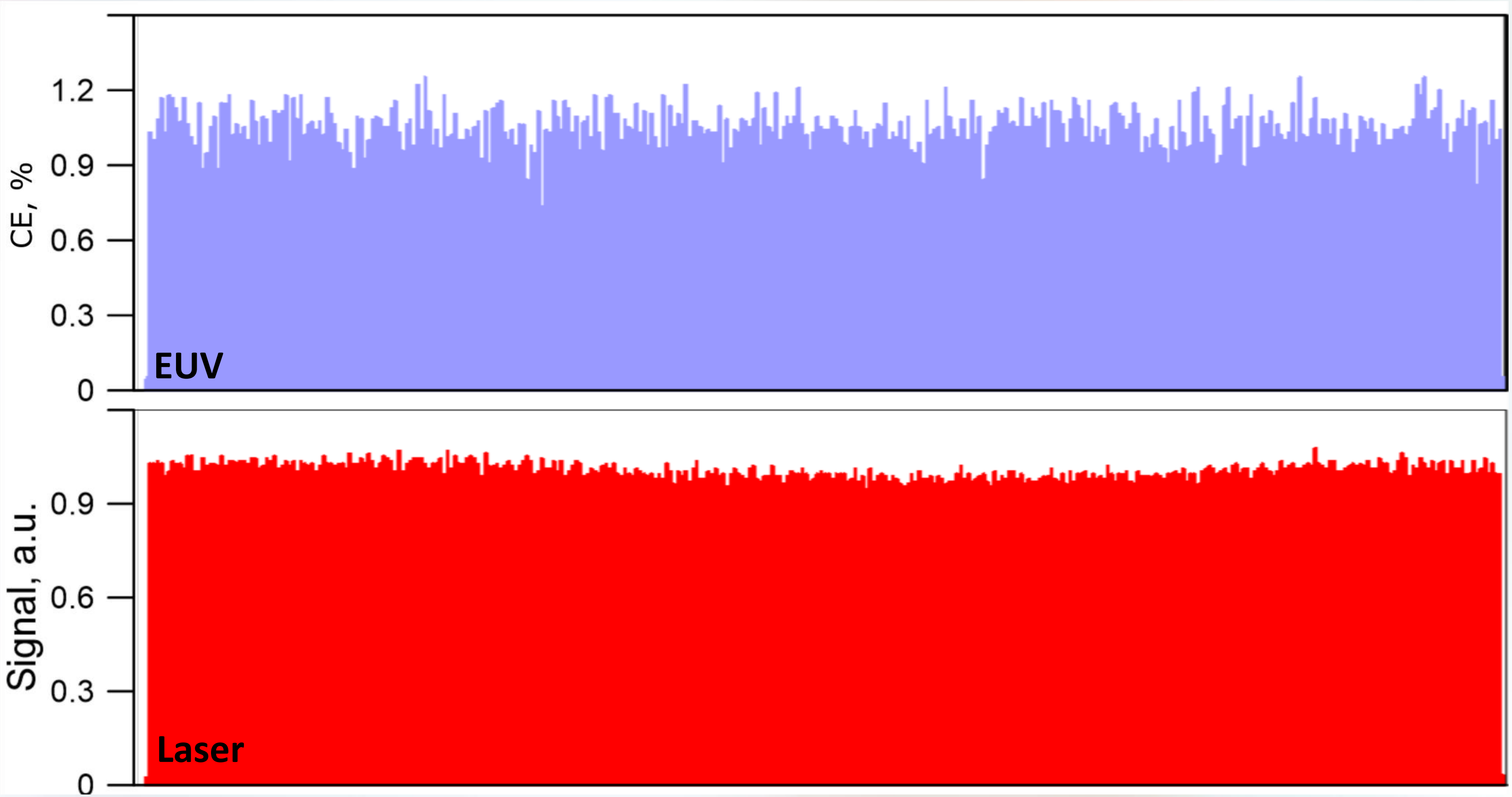
This data was gathered over a 6 hour period, number of shots - $5 \cdot 10^7$



- Proves the target and the optical windows can run for a long period of time with no need for intervention-30% degradation of the windows has been recorded due to the quality of the laser- explanation to follow
- With better laser parameters the source is extremely stable

Stability operation of the source

Stability operation was checked by using a Nd:YAG laser with PRR of 10 Hz, power density $0.8 \cdot 10^{11}$W/cm^2 and pulse duration of 15ns. 4 hours running:



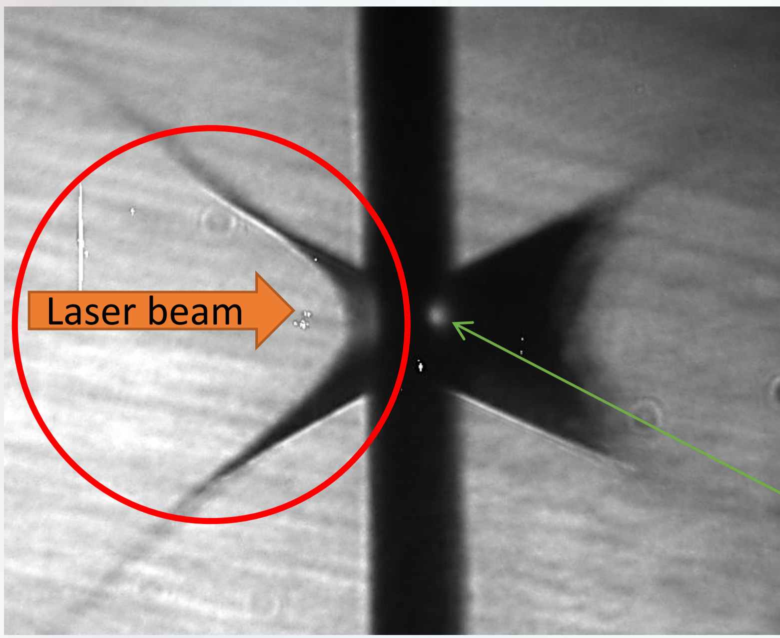
Time @10Hz

Debris control and management

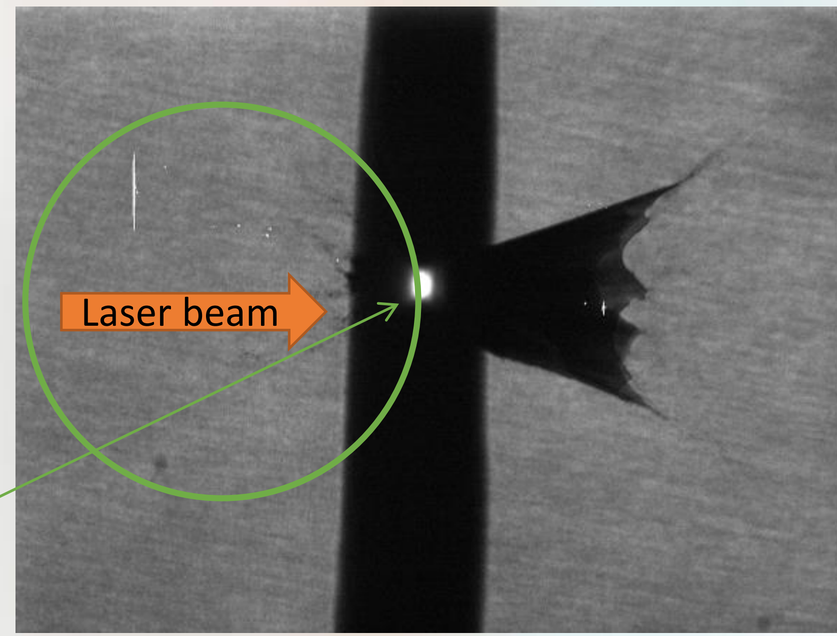
Using a special jet configuration and laser parameters for control of droplet debris flying towards input/output windows

The shadow photos of the of debris scattering at delay of 4us from laser pulse

Laser pulse duration of 50 ns (FWHM)



Laser pulse duration of 15 ns (FWHM)



Plasma

Droplet debris scattering towards input and output windows

Main Li jet source parameters using different lasers

Source and laser parameters \ Laser type		Supplier I 1 mJ, 30 kHz (30 W), $\Delta\tau$=2ns, M2<2	Supplier II 30 mJ, 20kHz (600W), $\Delta\tau$=8-14ns, M2<2	
Source size, um		30	30	100
Laser power density, W/cm²		$7*10^{10}$	$4*10^{11}$	$3.4*10^{10}$
CE, %/2π·sr		1	1.2	1.4
Photon flux, ph/pulse	At plasma	$5.6*10^{9}$	$1.6*10^{11}$	$1.8*10^{11}$
	After EUV window	$2.2*10^{9}$	$0.6*10^{11}$	$0.7*10^{11}$
Frequency, kHz		30	20	
Brightness ,W/mm²sr	At plasma	70	1600	170
	After EUV window	28	650	68
Collected in-band power, mW	At plasma	2.5	46	53
	After EUV window	1	18	21
Solid angle, sr		0.04 (NA=0.11)	0.04 (NA=0.11)	
Etendue, mm²·sr		$2.8*10^{-5}$	$2.8*10^{-5}$	$3.1*10^{-4}$

Summary

- 2 Beta sources have been completed; one to accommodate a low power laser and the other one for a high power laser
- Prototype to be assembled in 2018 with high laser power 1000+ W
- Long term running has been achieved
- CE, debris free and long term stability have been quantified

Thank you for your attention